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RESEARCH ARTICLE

Shareholder reaction to firm investments in the capability maturity model: an event study

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Abstract
This study investigates the differential effects of successfully completed capability maturity model (CMM) appraisals on a firm's short-term and long-term stock performance. Our results indicate a positive share price response on the days surrounding the appraisal date for the stocks of companies obtaining the CMM appraisal. Stocks of firms successfully completing CMM appraisals generally outperform the S&P 500 index over longer-holding periods, although they do not outperform a matched sample. We find support that firms from the information technology industry, firms that are larger, firms of higher CMM maturity levels, and firms completing multiple appraisals are more likely to experience both short-term and long-term benefits from their investing in the CMM.
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Introduction

Conceived by the Software Engineering Institute (SEI) at Carnegie Mellon, the Capability Maturity Model (CMM) has become the *de facto* standard for software and systems process development and improvement (Gefen & Zviran, 2006). The CMM is a compressive system/software process improvement framework used to guide firms in developing the means of managing the consistent delivery of high-quality software, systems, and information technology (IT)-related services within established budgets and timeframes (Krishnan *et al*, 1999). The CMM is divided into five maturity levels, Level 1 (initial) to Level 5 (optimizing). With the exception of Level 1, each level is associated with a set of prescribes process areas (PA). The CMM also contains a set of recommended practices that, when performed collectively and consistently, enable an organization to achieve the goals of the respective PA. These practices are intended to provide guidance to organizations on how to define and establish their own similar practices. Organizations move up levels of maturity by institutionalizing their own tailored practices that achieve the goals of the processes within a particular level. In the early Levels (2 and 3) of the CMM, firms establish well-defined, standardized project management and development processes. In the later Levels (4 and 5) of the CMM, firm establishes processes to track and eventually improve individual and collective process performance.

Successfully completing a CMM appraisal at any level is not trivial as firms must 'make substantial investments in firm infrastructure, systems, and human capital' (Ethiraj *et al*, 2005, p. 33). Worldwide, organizations have invested millions into CMM efforts in order to efficiently and effectively manage, standardize, control, measure, and improve software and systems development activities (Herbsleb *et al*, 1997).

Prior studies have contributed much to our understanding about the impact of CMM on product quality, process efficiency, and customer satisfaction (e.g., Krishnan & Kellner, 1999; Harter *et al*, 2000; Krishnan *et al*, 2000; Ramasubbu *et al*, 2008); however, there is relatively little research linking CMM investments to improved firm financial performance though such a link is assumed by many firms investing in the CMM. Using the event study methodology, this research seeks to address this gap in the literature while making some important contributions to both the IT and quality management (QM) literature. While the majority of event studies of IT investments use announcements of planned IT investments (some of which may not turn out to be successful), in contrast this research studies the impact of successfully completed CMM appraisals. Although there are several QM-related event studies, these studies use awards (which narrowly represent only the best firms involved in quality improvement, not all firms engaging in the activity) or certifications like ISO 9000 (which are not as specially or as compressively tailored for software/system development improvement). In contrast, this research focuses exclusively on the CMM appraisal over a period between 2006 and 2008.

In addition, this research extends recent studies on the firm-level benefits from CMM investments. Morris & Strickland (2008) examined the market's reaction to CMM investments, while Gao *et al* (2010) considered three contingency factors (vendor firm's offerings, the location of the vendor, and the extent to which CMM certification has penetrated within the competitive environment) related to vendors realizing benefits from the CMM in the Indian offshore IT services industry. This study extends their research by examining the differential impact of CMM investments based on various contextual factors such as industry, firm size, and the maturity of CMM implementation. We also consider both the short-term and long-term impacts of CMM investments on a firm's stock price and return on assets (ROA).

The remainder of the paper is organized as follows. We begin by reviewing the literature on the use of event study methodology, focusing on select studies directly relevant to this research. Next, drawing on a theoretical view of capabilities, the background theory and research hypotheses are presented. Subsequently the research method is discussed, including details regarding the various methodological approaches used to assess the short-term and long-term impacts of CMM investments. Next we present and discuss the results, providing several keen insights. The paper concludes with the limitations of the study, future research directions, and a summary of key contributions.

Related event study literature

Event study methodology is well established in the finance literature. The purpose of event study methodology is to determine whether firm announcements produce a 'significant' reaction in performance. To conduct such tests, returns or other such financial data are measured around the event date and compared with a control group. This section provides a review of two major streams of event study research directly relevant to the current study of CMM investments: (1) IT-related event studies and (2) QM-related event studies.

IT-related event studies

One of the earliest applications of the event study methodology in the IT literature was done by Dos Santos *et al* (1993), who concluded that IT-investment announcements did not significantly impact short-term performance; however, they did reveal that announcements that were considered 'innovative' showed statistically significant abnormal returns (ARs) within 1 day of the reported announcement. Using an updated sample, Im *et al* (2001) observed that smaller companies and announcements made by companies during the later years (1991–1996) produced significantly larger short-term ARs compared with the overall market.

Subsequent event studies began to investigate differences in firm performance due to the characteristics of the IT investment. Hunter (2003) found evidence that 'exploitative' investments (which decrease process variation through task automation or routinization) produce more reliable earnings as compared with 'exploratory' investments (which increase process variation through task experimentation and innovation). Interestingly, both types of investments announcements were for the most part associated with negative returns over several short-term event windows. Thus, Hunter reasoned that the impact of IT investments is strongly influenced by conditions within a specific industry. Chatterjee *et al* (2002), analyzing IT investment announcements associated with either a company's applications or infrastructure, found that although overall announcements had a significant and positive impact on a company's short-term share price and trading volume, the effect of IT infrastructure announcements was stronger.

IT-related event study research has also examined different types of firm-level IT investments, specifically enterprise systems. For example, Hayes *et al* (2001), Hitt *et al* (2002), and Ranganathan & Brown (2006) examined the impact of enterprise resource planning (ERP) system investments. All found a positive relationship between these investments and firm performance, both in terms of recent and expected future gains. Hitt *et al* (2002) and Ranganathan & Brown (2006) also showed that implementations with greater functional scope and/or physical scope resulted in higher levels of firm performance. Comparing various types of enterprise systems over a 1000-day time interval, Hendricks *et al* (2007) found evidence to suggest that differences in specific types of IT infrastructure had different impacts on a firm's performance. Their results showed that supply chain management (SCM) implementations had a positive impact on firm accounting measures and market value; ERP implementations had positive impact on accounting measures but not market value; and customer relationship management implementations had no significant impact on either type of measure. Dehning *et al* (2007), focusing solely on the impact of SCM systems, found a significant positive increase to firm accounting measures between 1 year prior and 1 after implementation, with this effect higher for high-tech firms.

IT-related event studies research is not limited to physical technology such as hardware and software; these include studies in contextual areas such as e-commerce (Subramani & Walden, 2001; Dewan & Ren, 2007), knowledge management (Sabherwal & Sabherwal, 2005; Sabherwal & Sabherwal, 2007); and standards setting (Aggarwal *et al*, 2011).

QM-related event studies

The QM literature has previously used the event study methodology to investigate the relationship between QM practices and firm performance. The majority of these studies have either used quality awards or specific quality-related certifications (e.g., ISO 9000) as proxy measures. However, the long-term and short-term impact of these QM initiatives on firm performance has been mixed.

Hendricks & Singhal (1996, 1997, 2001b) found evidence to suggest that quality awards were related to both short-term and long-term firm performance. Using in-depth interviews in conjunction with publicized quality award announcements, Easton & Jarrell (1998) found evidence that also suggests that TQM programs are associated with long-term firm performance. Hendricks & Singhal (2001a) found that quality award winners do perform better and that winners that are smaller in size, less capital-intense, or with more mature implementations performed significantly better over the long term than larger, more capital-intense or less mature implementers. Examining two specific types of quality rewards, Malcolm Baldrige National Quality Awards (MBNQA) and J.D. Power and Associates Awards (JDPAA), Balasubramanian *et al* (2005) found that MBNQA winners did see increases in firm performance in the short term, but JDPAA winners saw no significant impact on firm performance. No performance effect was found for either group over three increasing, 6-month time periods. Adams *et al* (1999)'s analysis revealed that national awards had only a marginally significant positive effect on short-term firm performance, while state-level awards showed no significant effect. Adjusting for market and industry effects, Przasnyski & Tai (1999, 2002)'s results indicated that there was little to no evidence to support earlier claims of the short-term impact and no evidence to support earlier claims of long-term positive impact of quality awards on firm performance. Furthermore, their results revealed that quality award winners significantly underperformed similar firms in the same industry.

The impact of specific quality certifications such as ISO 9000 on firm performance has also been mixed. Simmons & White (1999) found evidence to suggest that firms in the electronics and electrical component industry with ISO 9000 certification performed better in term of ROA than non-certified firms in the same industries. Considering manufacturing firms, Corbett *et al* (2005) showed that ISO 9000 certified companies exhibit improved long-term accounting-based financial performance when compared with a matched sample, based on industry and size, of non-certified firms. Docking & Dowen (1999) revealed a positive short-term market reaction to ISO 9000 certification but only for small firms within their sample. McGuire & Dilts (2008) found little statistically significant evidence to support the positive impact of ISO 9000 certification on short-term firm performance. However, their results did show that smaller firms and firms certified in the more recent ISO 9000 standard (ISO 9001:2000) had moderately significant and positive market returns. Fuller & Vertinsky (2006), who examined the impact of ISO 9000 on firm performance of 23 large and small software development and integration companies, showed that certification was associated with an increase in short-term firm performance only for companies engaged in producing software products, not supplying software service. There was also no significant positive effect associated with firm size.

Summary analysis of IT-related and QM-related event studies

This section presents several important observations from the above review of the IT-related and QM-related event studies. First, most IT-related event studies focus on IT investments associated with hardware or software while the majority of QM-related event studies are associated with process improvement efforts. The majority of IT-related reported events are proposed investments but not actually completed (which may or may not turn out successful). In contrast, the majority of the QM-related events are successfully completed efforts that have been culminated with a certification or quality award. Data regarding IT-related events are gathered from various news and press outlets including Lexis/Nexis, while several QM-related event studies, specifically those investigating the impact of ISO 9000 (e.g., Fuller & Vertinsky (2006), Corbett *et al* (2005), Docking & Dowen (1999), and Simmons & White (1999)), use web sites and registry databases containing detailed certification and award data.

Until recently, IT-related event studies have focused solely on short-term impacts on firm performance. In contrast, QM-related event studies have an extensive history of examining both the short-term and long-term impacts. In a related comparison, IT-related event studies predominately examine firm performance using financial data, while QM-related event studies use a mix of financial and accounting data. However, an examination of both streams of research reveals that differences in industry, firm, investment type, and performance measures can influence the direction, magnitude, and significance of the impact.

Before concluding this section, mentioning two additional studies is important. Morris & Strickland (2008), using 98 announcements made by 54 unique firms found through searching Lexis/Nexis, also studied the market's reaction to CMM investments. Their results show that firms do benefit in the short term from CMM investments. Gao *et al* (2010), studying the Indian offshore IT services industry, revealed that the beneficial impact of the CMM may be conditional with respect to various vendor and environmental factors. Our research seeks to expand on the work of Morris & Strickland (2008) and Gao *et al* (2010), as well as others mentioned in this review, by investigating additional contextual and performance-related factors associated with CMM investments.

Theoretical perspective and research hypotheses

The resource-based view provides a theoretical basis linking a firm's resources to its performance. The theory uses an efficiency-based explanation to prescribe why some firms outperform others (Peteraf & Barney, 2003). Resources are said to be a source of competitive advantage if they are valuable (improve efficiency and effectiveness), appropriable (the value generated exceeds the costs associated with the benefit), and rare (not simultaneously possessed by a larger number of firms) (Barney, 1991; Mata *et al*, 1995). The competitive advantage generated by these resources is more difficult to imitate when the resources develop over a long period of time, evolve through socially complex networks, and have a high degree of casual ambiguity surrounding their impact on firm performance (Barney, 1991; Mata *et al*, 1995). Such observation regarding the complexity of successful CMM implementations have been made in the IT literature (Ethiraj *et al*, 2005; Gefen & Zviran, 2006; Ramasubbu *et al*, 2008).

The arguments for a positive effect on the market value of a successful CMM appraisal relate to both its original use of the CMM as a vendor qualification mechanism and its later application as a process improvement framework. The CMM prescribes to the belief that software and systems can be more efficiently and effectively produced thorough well-managed, defined, controlled, and measured organizational processes (Jiang *et al*, 2004), the theoretical foundation of which are rooted in the TQM literature. Proponents of the CMM claim that consistently performing defined processes increase an organization's ability to meet its cost, quality, schedule, and performance objectives (Herbsleb *et al*, 1997). Several empirical studies have found a link between increased organizational process capabilities, similar to those defined by the CMM, and improvements in cycle time, cost control, productivity, and quality (Herbsleb *et al*, 1994; Deephouse *et al*, 1995–1996; Herbsleb *et al*, 1997; Krishnan & Kellner, 1999; Clark, 2000; Harter *et al*, 2000; Krishnan *et al*, 2000; Jiang *et al*, 2004; Agrawal & Chari, 2007). Harter & Slaughter (2003) also found evidence to suggest that the firm's costs, specifically the cost of infrastructure activities supporting software/system development, are further reduced as a result of increases in quality from software/systems process improvement efforts. Researchers have proposed that these improvements in quality and efficiency will impact the supply and demand sides of a firm (Gao *et al*, 2010). Improvements in output quality will potentially lead to increased market share and revenues, while improvements in internal efficiency will lower a firm's average costs as well as potentially raise sales levels and revenue through better utilization of slack resources (Hendricks & Singhal, 1997; Corbett *et al*, 2005; Gopal & Gao, 2009).

Such impacts will manifest both in the short term and long term through signaling and continuous process improvement, respectively. It is more likely that any effect from signaling would be short term, since signaling effects are strongest around the event date and diminish over time (Gopal & Gao, 2009), while the effect from continuous process improvement may not be readily visible and may take longer to materialize as small incremental adjustments accumulate (Hendricks & Singhal, 1997, 2001a, b; Easton & Jarrell, 1998; Corbett *et al*, 2005).

Therefore, based on the above arguments and past empirical evidence, we hypothesize the following:

H1A: *Successful CMM implementations will have a short-term positive impact on a firm's financial performance.*

H1B: *Successful CMM implementations will have a long-term positive impact on a firm's financial performance.*

Contextual factors

Past TQM and IT event study research has identified several contextual factors that aid in explaining the strength and direction of the market reaction. This research considers the main effects of three such factors identified from prior event studies: industry classification, firm size, and maturity of implementation.

Industry classification Past IT-related event studies research have examined possible industry effects with respect to financial *vs* non-financial (Im *et al*, 2001; Chatterjee *et al*, 2002; Oh *et al*, 2006), service *vs* non service/manufacturing (Dos Santos *et al*, 1993; Hayes *et al*, 2000; Chatterjee *et al*, 2002), high-tech *vs* non high-tech (Dehning *et al*, 2007) and IT-producing *vs* IT-using (Chatterjee *et al*, 2002) firms. However, support for these effects has been mixed. Given the possible differentiated effects with respect to industry classification, this research examines potential differences with respect to IT *vs* non-IT firms.

Although CMM practices are predominately associated with IT firms, it is not uncommon for non-IT organization to adopt CMM processes and practice, particularly firms with products or services containing or dependent on software for their functionality. Several non-IT firms even have IT departments of a size that rival some of the largest IT firms. Examples from the literature of non-IT firms that have adopted the CMM include Hughes (Humphrey *et al*, 1991), Raytheon Corporation (Haley, 1996), and Schlumberger (Wohlwend & Rosenbaum, 1994). On the basis of a recent report by the SEI on CMM appraisals (CMMI, Product Team, 2009), of the 2652 organizations reporting Standard Industrial Classification (SIC) codes, 17.5% were classified in areas of manufacturing, and approximately 24% of the service firms were classified in the areas of transportation, finance, or health services with another 21% classified as other, non-specific, service industries.

Although there has been a significant number of non-IT firms that have adopted the CMM, investors may place little value on CMM appraisals outside the IT industry as investors may not associate the potential benefits from the CMM with non-IT firms. In addition, although investors may view software/system development as a core competency of IT firms, they may believe that non-IT firm would be able to attain the same or similar level of software/system development capabilities as their competitors through outsourcing (Hayes *et al*, 2000; Gewald & Gellrich, 2007; Wang *et al*, 2008). Therefore, we hypothesize the following:

H2A: *The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for IT firms than for non-IT firms.*

IT firms have more specialized IT knowledge, greater investments in IT, and a larger portion of their operational activities and revenue directly and indirectly associated with software/system development. As a result, CMM related, improvements in quality, process performance, control, coordination, and knowledge integration will have a greater impact on their long-term organizational performance when compared with non-IT firms. In addition, these firms will be more able to spread the cost associated with CMM over more projects, customers, and/or operating divisions. Therefore, we hypothesize the following:

H2B: *The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for IT firms than for non-IT firms.*

Firm size Capital market theory proposed that markets efficiently incorporate publicly available information into the valuation of a firm's stock price. Information regarding firm performance and activities tends to be disclosed more often for larger firms than smaller firms. Thus, the effect of the CMM appraisal will be stronger for smaller firms since such information may be new to investors, at least in the short term (Hayes *et al*, 2000). Both TQM-related (Hendricks & Singhal, 1996; Docking & Dowen, 1999) and IT-related (Hayes *et al*, 2000; Im *et al*, 2001; Chatterjee *et al*, 2002) event studies have provided empirical evidence to suggest this possible negative correlation between short-term market reaction and firm size. Therefore, we hypothesize the following:

H3A: *The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for smaller firms than for larger firms.*

There are several prevailing views regarding the effect of firm size on long-term competitive performance of a firm. One view proposes that smaller firms are more adaptive since the organizational inertia required for change is lower in these firms, while larger firms tend to have more specialized areas of knowledge, levels of communication, and dispersed work force making change more difficult and expensive. It has been argued that both TQM and IT-related investments require organizational change; and thus smaller firms are more likely to generate greater returns on such investments (Hendricks & Singhal, 2001a; Meng & Lee, 2007). However, this research investigates successful CMM implementation so it can be assumed that these larger organizations have overcome (or at least a have the ability to overcome) the resistive inertia associated with change. Another view is based solely in the IT literature and proposes that larger firms benefit more from IT investments which enable coordination or control (Dewan *et al*, 1998; Meng & Lee, 2007). Researchers have suggested that while the formal process practices prescribed by the CMM facilitate control and coordination of diverse tasks in large firms, they also can be counterproductive, bureaucratic, extremely complex, and difficult to implement in smaller firms (Ngwenyama & Nielsen, 2003). In addition, there is the possibility that the CMM may reduce productivity, curtail creativity, and greatly increase overhead costs in smaller firms (Kelly & Culleton, 1999). Finally, larger firms are more likely to have slack resources; thus, improvements costs and revenue through better utilization of these resources may be more pronounced in larger firms. On the basis of the arguments presented, it is proposed that the benefits associated with successful CMM implementations would be more prevalent in larger firms. Therefore, we hypothesize the following:

H3B: *The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for larger firms than for smaller firms.*

Maturity of implementation Ranganathan & Brown (2006) characterized the maturity of an IT infrastructure implementation with respect to both physical and functional scope. They defined physical scope in terms of the number of sites (divisions or geographic) involved in the implementation and function scope in terms of the number of direct valued added activities encompassed by the implementation. Consistent with Ranganathan &

Brown (2006), we define physical scope in terms of the number of CMM implementations by a firm. To measure functional scope in the context of their research on ERP investments, Ranganathan & Brown (2006) used the number of value-chain modules implemented, with multiple modules and full suite implementations representing higher functional scope. In the context of the CMM, we use a similar approach by measuring functional scope in terms of higher CMM maturity levels. Achievement of a higher maturity level reflects the successful implementation of additional processes and practices central to meeting performance expectations of the customer and facilitating organizational learning (Krishnan & Kellner, 1999; Harter *et al*, 2000; Ramasubbu *et al*, 2008).

The CMM hierarchy consists of five maturity levels. Level 1 represents the least mature stage where an organization has no formally defined and consistently performed PAs associated with developing software/systems. Organizational learning takes place as a firm's process capability matures over time. Level 5 is the highest, most mature stage; organizations at Level 5 have successfully implemented all the PAs prescribed CMM. Paulk (1995) suggested that firms at Level 2 are equivalent to ISO 9000-certified organizations. Passage to Level 3 through Level 5 maturity represent significant improvement, as firms move from using formally defined and consistently performed processes and to actively engaging in continuous process improvement (Keeni, 2000). Achieving a higher CMM maturity level signals to investors that the organization is engaged in quality initiatives (Gopal & Gao, 2009). McGuire & Dilts (2008) found empirical support that the markets react positively in the short term to more stringent standards. Therefore, we hypothesize the following:

H4A: *The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of greater functional scope (higher maturity levels) than for implementations of lesser functional scope (lower maturity levels).*

The QM-related event studies in the literature has provided empirical evidence which suggests that organizations that are more mature in process improvement perform better in the long run than less mature organizations (Easton & Jarrell, 1998; Hendricks & Singhal, 2001a). The CMM prescribes that achieving higher levels of maturity results in project outcomes that are more predictable and involve little or no rework, defects, and schedule delays (Jiang *et al*, 2004). Empirical evidence shows the greater number of well-established and consistently performed processes as defined by the CMM lead to reduction in defects and improve software quality (Krishnan & Kellner, 1999; Krishnan *et al*, 2000). Herbsleb *et al* (1997), using data collected on 104 CMM appraisals involving 48 companies, showed evidence that increases in maturity levels had a significant correlation with increased software quality, customer satisfaction, productivity, staff morale, and the ability to meet budgets. Agrawal & Chari (2007), analyzing data on 37 software projects from four organizations at Level 5, found evidence of significant reductions in variances associated with effort, quality, and cycle time in projects by Level 5 firms. Hunter (2003) showed that IT investments that decreased process variation through routinization produce more reliable earnings than IT investments that increase process variation, while Easton & Jarrell (1998) revealed that firms with more advanced quality efforts perform better in the long term than firms with less advanced efforts. Therefore, we hypothesize the following:

H4B: *The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of greater functional scope (higher maturity levels) than for implementations of lesser functional scope (lower maturity levels).*

Physical scope, in this study, refers to the number of formal organization units within a single firm that have completed a successful CMM appraisal. Here again we draw on capital market theory and the efficiency of the markets. More likely, at least in the short term, information regarding an initial implementation would be more valuable to investors than a subsequent announcement, since, to the investor, this announcement would represent new information. Investors who perceive value in CMM implementation would more likely be tracking firms after their initial appraisal for possible disclosure of more implementations. The more scrutinized tracking by investors would lead to more premature leakage of CMM appraisal information and thus delude the impact on the event date. Therefore, we hypothesize the following:

H5A: *The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of lesser physical scope (initial implementations) than for implementations of greater physical scope (multiple implementations).*

Over time, the CMM can significantly improve operations as more organizational units adopt the same processes, routines, and technology, and there is increased potential for greater sharing and leveraging of information and best practices (Ranganathan & Brown, 2006). Through formal processes, knowledge can be accumulated, articulated, and codified, thus making it easier to diffuse throughout the firm (Ravichandran & Rai, 2003). The CMM has been found to aid in the generation and integration of system/software development knowledge in distributive and disperse work environment (Ramasubbu *et al*, 2008). Empirical evidence has shown that IT infrastructure investments of greater physical scope are significantly and positively related to firm performance (Ranganathan & Brown, 2006). Therefore, we hypothesize the following:

H5B: *The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of greater physical scope (multiple implementations) than for implementations of lesser physical scope (initial implementations).*

Methodology and results

Sample selection and description of the CMM sample

Organizations are not certified in the CMM; rather, organizations are appraised. There are three different classes of appraisals: A, B, and C. The most rigorous method is the Class A appraisal, also known as the Standard CMMI Appraisal Method for Process Improvement (SCAMPI). It is also the only appraisal method for which an organization can get an official SEI level rating (from 1 to 5). The SCAMPI appraisal method consists of a set of pre-on-site activities, on-site activities, and post-on-site activities. Median time requirements, reported by the SEI, for pre-on-site and on-site activities are 37 and 62 h, respectively; the reported median time for the entire appraisal method is 96 h (CMMI Product Team, 2006).

We retrieve the published results of CMM Class A appraisals between 2006 and 2008 from the web site http://sas.sei.cmu.edu/pars/pars.aspx, which comprises our CMM overall sample. To be included in the sample, each firm must meet the following criteria:

1. The sample firms must have return records on the Center for Research on Stock Prices (CRSP) Daily Combined Return File 326 days immediately before the published appraisal date.
2. The sample firms must have return records on the CRSP Daily Combined Return File 1 year after the appraisal end date.

From an original sample of 2050 appraisals, 492 had data listed on CRSP with 348 observations meeting the two criteria.

Next, for the purposes of establishing an appropriate benchmark for comparative performance, we construct two matched samples: (1) industry and size match on the basis of market capitalization and industry classification based on two-digit SIC codes, and (2) industry and performance match (the previous year's ROA) on the basis of market capitalization and industry classification. The goal in creating a benchmark is to provide an improved basis for comparative analysis over a broad-market index. In addition, we compare the investment performance of the sample firms to the larger, more diversified S&P 500 index. We retrieve market capitalization for each firm 1 month before each observation's appraisal date from CRSP data and calculate the previous year's ROA for each firm using accounting-based data retrieved from the Compustat database. Our potential universe of matching firms consists of all remaining stocks that have available data from CRSP within the same industry and have no CMM implementation in their histories. In order to derive the best possible match for each firm in our CMM sample, we choose the stock with the closest market capitalization (or closest previous year's ROA) within the same industry. We repeat the procedure for each sample firm in our study.

In order to test short-term and long-term stock price reactions of published appraisals based on different industry, firm size, levels of maturity, and whether the announcement represents an initial or subsequent level appraisal, we develop different sub-samples. Specifically, we construct the following 10 sub-samples:

- IT Industry: firms with the first two digits of their SIC code as '73', the first three digits of their SIC codes as '357' (computer and office equipment) and '368' (computer hardware) were assigned to the IT sub-sample, all others were coded non-IT.
- Firm Size: firms were assigned to the smaller firm or larger firm sub-samples according to the event firm's market capitalization during the event month. To the extent that larger firms are more likely to implement CMM, our smaller firm sub-samples may contain relatively larger firms. Therefore, we calculate the sample mean and median of all stocks that have available data during our sample period. The average market capitalization is around US$2627 million with a median of $2734 million. Our smaller firm sub-samples has a higher average market cap ($4259 million) than the total sample but has a similar median value of market cap ($2612 million) when compared with the total sample. In addition, in order to control the possible effect of firm size, we compare the performance of firms in the CMM sample with their industry and size-matched firms to draw meaningful conclusions.
- Functional Scope (maturity level): lesser and greater function scope corresponds to lower and higher maturity level appraisal events, respectively; three sub-samples were created based on maturity level: Level 2, Level 3, and Level 4 and 5 (given the small number of 4 and 5 maturity level events, event data associated with Levels 4 and 5 were combined into a single sub-sample).
- Physical Scope (appraisals): events assigned to the initial appraisal (lesser physical scope) sub-sample were the initial appraisal event for each firm over the data period; events assigned to the multiple appraisals (greater physical scope) sub-sample were subsequent appraisal events from firms with more than one appraisal over the data period.

Table 1 shows the descriptive statistics of our CMM overall sample, each of our sub-samples, and the matched sample. Table 1a reveals that firms with multiple appraisals are associated with larger market capitalization. A test of the sample distribution (reported in Table 1b) shows that over 86% of the large sample stocks (150 out of 174) have multiple appraisals. This relationship is progressive as the average market capitalization for

Table 1 Descriptive statistics and sample distribution

(a) Descriptive statistics for CMM sample, matched sample, and sub-samples

Variable	*Number of events*	*Mean*	*Standard deviation*	*Percentile*				
				Minimum	*25*	*50*	*75*	*Maximum*
Market capitalization (millions)								
All CMM	348	29,224	44,556	10	2612	16,392	27,783	397,142
IT	143	37,687	51,296	10	2484	17,082	25,459	263,752
Non-IT	205	23,295	38,177	33	2684	12,313	29,246	397,142
Smaller	174	4259	3925	10	1409	2612	7079	15,933
Larger	174	54,189	52,084	16,851	24,148	27,783	74,078	397,142
Level 2	66	21,129	35,288	33	2033	7079	26,059	171,414
Level 3	215	29,583	47,800	10	2781	16,851	26,059	397,142
Level 4 and 5	67	38,139	41,399	25	7428	24,616	42,022	158,746
Initial appraisal	98	25,433	57,703	10	922	3113	14,994	397,142
Multiple appraisals	250	29,218	37,442	90	3949	21,207	29,246	159,392
Industry and size match	348	26,761	37,143	10	2625	15,464	30,135	200,152
Industry and performance match	348	3118	7562	3	223	709	1985	45,085

(b) Sample distribution of sub-samples

Variable	*Initial appraisal*	*Multiple appraisals*	*IT*	*Non-IT*	*Smaller*	*Larger*
Initial appraisal ($n=98$)	98					
Multiple appraisals ($n=250$)		250				
IT ($n=143$)	29	114				
Non-IT ($n=205$)	69	136				
Smaller ($n=174$)	74	100	66	108		
Larger ($n=174$)	24	150	78	96		
Level 2 ($n=66$)	30	36	15	51	44	22
Level 3 ($n=215$)	54	161	100	115	107	108
Level 4 and 5 ($n=67$)	20	47	31	36	19	48

Level 2 sub-sample is $21 billion, while those of the Level 3 and 4 and Level 5 sub-samples are $29.6 and $38 billion, respectively, where about 70% of the Level 4 and 5 sub-sample stocks (47 out of 67) are larger firm sub-sample stocks. However, this seems reasonable given the increased investment in infrastructure and human capital required to move up levels (Herbsleb *et al*, 1997; Ethiraj *et al*, 2005). Although the IT sub-sample has, on average, a relatively larger market capitalization than the overall CMM sample, the sample is evenly distributed among larger and smaller firms, as about half of the IT stocks (78 out of 143) belong to the larger firm sub-sample.

Stock performance of the CMM sample

In this section, we examine the announcement effects of the adoption of CMM framework. Our tests are conducted in two parts. First, in Section A, we examine the short-run market impact for the CMM sample using standard event study. Then we examine the long-run stock performance using methods described in Section B.

Section A: short-run market impacts H1A–5A proposes various short-term positive market reactions to CMM investments. These hypotheses assume that market perceive the CMM as positive based on the assumption that investors believe the CMM benefits (e.g., from increased efficiency) outweigh the investment cost. However, it is possible that the market may show no response, which would indicate that investors perceive the accumulated returns associated with the CMM are not higher than the investment cost. Finally, the market may respond negatively, indicating that investors perceive the cost incurred by the firm to achieve the CMM appraisal outweighs any returns generated by the investment.

We test the share price response to the CMM appraisal rating beginning 5 days before the appraisal end date by calculating daily ARs and cumulative abnormal returns (CARs) over our event window (from days −5 to +5). Expected returns are estimated from the market model during the interval (−5, 5), and estimates of the parameters are calculated for the period (−326, −71). We follow Dodd & Warner (1983) and employ standard event-study methodology.

Table 2 reports the results of the event study for the CMM sample and sub-samples. Panel 1 shows the ARs around the event date, and Panel 2 shows the CARs. The overall CMM sample results indicate a positive stock price impact around the press release date. With the exception of the non-IT sample, the whole sample and the remaining eight sub-samples show a significant positive AR at a 5% level or greater the day of and/or the day after the event date. Also interesting to note is that the IT, Smaller Larger Level 2, Level 4 and 5, and Initial Appraisal sub-samples all had a significant negative AR at least once 1–3 days before the event date.

For the entire CMM sample, we observe a statistically significant (at the 1% level), positive CAR of 0.43% over the event window of (−1, +1) and a statistically significant (at the 10% level), positive CAR of 0.25% over the event window of (−2, +2). Overall, the AR and CAR results associated with the whole sample support H1A. Looking across the different sub-samples, we first observe IT firms having a statistically significant (at the 1% level), positive CAR of 0.70% over the (−1, 1) window and a statistically significant (at the 10% level), positive CAR of 0.37% over the event window of (−5, 5), while the non-IT sample shows only marginally significant returns during the event window (−1, +1) and no statistically significant returns over other event windows. Thus, both the AR and CAR results are consistent with H2A; IT industry classification makes a difference in market reaction.

Examining the sub-samples based on firm size, we observe that the sub-sample containing larger firms has a statistically significant, positive CAR of 0.55 and 0.40% over the event window of (−1, 1) and (−2, 2), respectively, while the corresponding figures for the sub-sample of smaller firms are statistically insignificant. Thus, contrary to H3A, larger firms seem to benefit more in the short term from the CMM appraisal than smaller firms.

We also observe differences in market reaction to both the functional and physical scope of the CMM appraisal. With respect to the functional scope, we observed that a statistically significant 0.58 and 1.04% CARs exists over the event window of (−1, 1) and (−2, 2) for our Level 2 sub-sample, a statistically significant 0.35% CAR over the event window of (−1, 1) for our Level 3 sub-sample, and an insignificant CAR for our Level 4 and 5 sub-sample. However, taking a closer look at the CAR associated with the event windows for the Level 4 and 5 CAR value, we see two very large negative ARs 2 days before the event date. Thus, we conclude there is no definitive indication based on the data to confirm or refute H4A. However, there is evidence to suggest that short-term ARs can be generated from each maturity level appraisal. Finally, with respect to the physical scope of the CMM appraisal, we observed for the multiple CMM appraisal sub-sample a statistically-significant (at the 1% level), positive CAR of 0.37% over the event window of (−1, +1), compared with a statistically significant (at the 10% level), positive CAR of 0.53% during the same event window for initial appraisal sub-sample. Again, we cannot with confidence confirm or refute H5A. However, we can state based, on the analysis of the data, that CMM appraisals (be it the initial appraisal or through multiple appraisals) do add value in the short term.

Section B: long-term stock return performance In this section, and unlike previous research on IT investments and specifically the CMM appraisals, we examine the long-term return performance of the CMM overall sample in periods following each appraisal date. Numerous researchers (e.g., Barber & Lyon (1997), Fama (1998), and Loughran & Ritter (1995)) have shown that the magnitude, and sometimes even the sign, of the long-run ARs are sensitive to alternative measurement methodologies.

Table 2 Event study results for CMM sample and sub-samples

All CMM (n = 348)			*IT (n = 143)*		*Non-IT (n = 205)*		*Smaller (n = 174)*		*Larger (n = 174)*	
Day	*AR*	*z-statistics*	*AR*	*z-statistics*	*AR*	*z-statistics*	*AR*	*z-statistics*	*AR*	*z-statistics*
Panel 1: Abnormal returns (%) around event date										
−5	−0.02	−0.36	−0.01	−0.00	−0.02	−0.47	−0.08	−0.90	0.05	0.38
−4	0.13	2.07**	0.31	2.63***	0.01	0.50	0.12	1.77	0.14	1.15
−3	−0.09	−0.67	−0.17	−0.40	−0.04	−0.53	−0.31	−2.25**	0.12	1.29*
−2	−0.06	−1.13	−0.18	−0.32	0.02	−1.21	0.05	0.36	−0.17	−1.96**
−1	0.04	−0.04	−0.32	−1.76**	0.30	1.42*	−0.03	−0.97	0.12	0.91
0	0.17	1.63*	0.45	2.88***	−0.02	−0.28	0.28	1.99**	0.07	0.32
1	0.21	3.39***	0.58	3.85***	−0.04	1.20	0.06	0.25	0.36	4.52***
2	−0.12	−0.93	−0.21	−1.58*	−0.06	0.10	−0.27	−1.69**	0.02	0.37
3	−0.07	−1.30*	0.01	0.34	−0.13	−1.97**	0.12	0.84	−0.25	−2.66
4	−0.15	−0.73	−0.17	−0.97	−0.14	−0.15	−0.32	−1.51*	0.01	0.46
5	0.06	0.58	0.08	0.22	0.06	0.57	0.01	−0.49	0.12	1.30*
Interval	*CAR*	*z-statistics*	*CAR*	*z-statistics*	*CAR*	*z-statistics*	*CAR*	*z-statistics*	*CAR*	*z-statistics*
Panel 2: Cumulative abnormal returns (%) around event date										
(−5, −2)	−0.04	−0.05	−0.05	0.96	−0.03	−0.86	−0.22	−0.50	0.14	0.43
(−1, 0)	0.22	1.13	0.13	0.80	0.28	0.8	0.25	0.72	0.19	0.87
(1, 5)	−0.07	0.45	0.29	0.83	−0.32	−0.11	−0.40	−1.16	0.26	1.78**
(−1, 1)	0.43	2.87***	0.70	2.87***	0.24	1.35*	0.31	0.73	0.55	3.32***
(−2, 2)	0.25	1.30*	0.32	1.38*	0.19	0.55	0.09	−0.03	0.40	1.86**
(−5, 5)	0.11	0.75	0.37	1.47*	−0.06	−0.25	−0.37	−0.78	0.59	1.84**

Level 2 (n = 66)			*Level 3 (n = 215)*		*Level 4 and 5 (n = 67)*		*Initial appraisal (n = 98)*		*Multiple appraisals (n = 250)*	
Day	*AR*	*z-statistics*	*AR*	*z-statistics*	*AR*	*z-statistics*	*AR*	*z-statistics*	*AR*	*z-statistics*
Panel 1: Abnormal returns (%) around event date										
−5	−0.01	0.46	0.03	0.01	−0.17	−1.30	0.27	0.96	−0.04	−0.26
−4	−0.29	−0.39	0.28	2.66***	0.09	0.34	0.03	1.07	0.18	2.20**
−3	−0.50	−2.22**	−0.06	−0.22	0.21	1.07	−0.38	−3.53***	−0.06	0.19
−2	0.52	0.95	−0.04	−0.65	−0.69	−2.36***	0.29	1.25	−0.09	−1.11
−1	0.61	1.33*	0.09	0.96	−0.68	−3.12***	0.11	−0.27	0.03	0.26
0	−0.23	−1.34*	0.17	1.68**	0.60	2.04**	0.33	2.17**	0.15	1.35
1	0.20	2.64***	0.09	1.31*	0.63	2.75***	0.09	0.81	0.19	2.80***
2	−0.06	0.37	−0.11	−1.01	−0.22	−0.69	−0.12	−0.47	−0.13	−0.79
3	0.28	1.23	−0.23	−2.66***	0.11	0.58	−0.04	−0.97	−0.07	−0.94
4	−0.01	1.25	−0.15	−1.19	−0.31	−0.78	−0.08	0.53	−0.15	−0.86
5	−0.09	−0.41	0.14	1.26	−0.03	−0.53	0.09	−0.42	0.02	0.72

Table 2 Continued

Interval	*CAR*	*z-statistics*	*CAR*	*z-statistics*	*CAR*	*z-statistics*	*CAR*	*z-statistics*	*CAR*	*z-statistics*
Panel 2: Cumulative abnormal returns (%) around event date										
(−5, −2)	−0.27	−0.60	0.20	0.90	−0.55	−1.13	0.20	−0.12	−0.01	0.51
(−1, 0)	0.38	−0.01	0.26	1.87**	−0.07	−0.76	0.44	1.35*	0.18	1.14
(1, 5)	0.32	2.27**	−0.26	−1.03	0.17	0.60	−0.06	−0.23	−0.13	0.41
(−1, 1)	0.58	1.52*	0.35	2.28**	0.55	0.96	0.53	1.57*	0.37	2.55***
(−2, 2)	1.04	1.77**	0.19	1.02	−0.35	−0.62	0.70	1.56*	0.15	1.12
(−5, 5)	0.43	1.17	0.19	0.65	−0.45	−0.60	0.58	0.34	0.04	1.07

*Significant at 10% level, ** significant at 5% level, ***significant at 1% level.

To determine the sensitivity of our test results, we examine the long-term return performance of the CMM firms with different methodologies.

Long-Term CARs: Annualized Raw Returns: We initially test the long-run stock performance of the CMM sample by 'buying' the CMM stock on its appraisal end date (i.e., on the announcement date of the each appraisal). This stock is 'held' until 1 year after the appraisal date. We use three types of benchmark portfolios to test the ARs of the CMM sample: the S&P 500 index, industry/size matched sample, and industry/performance matched sample. Using these groups provides a more detailed comparison as we see how the various CMM samples compare to the market in general (i.e., S&P 500 index), firms of the similar size (i.e., size matched sample), and firms in similar financial position (i.e., performance matched sample). To determine ARs, we calculate both the traditional CARs and buy-and-hold abnormal returns (*BHAR*s) over the 1-year holding period. We define R_{it} as the date t simple return on the CMM firm i, $E(R_{it})$ as the date t expected return for the firm, and $AR_{it}=R_{it}-E(R_{it})$ as the AR in date t. In this case, we use the S&P 500 daily returns and stock i's matched return as $E(R_{it})$. Cumulating across T trading days (i.e., T is the number of trading days until 1 year after the appraisal date) yields the CAR:

$$CAR_{iT} = \sum_{t=1}^{T} AR_{it}. \quad (1)$$

Table 3 reports the annualized raw returns for the CMM overall sample and the three benchmark portfolios. For each stock in the CMM overall sample, we calculate its CAR compared with the benchmark portfolio over the holding period and use the paired *t*-test to determine whether the CAR is significantly different from 0.

Comparing the cumulative raw returns of the entire CMM sample with the S&P 500 index, the CMM sample shows a positive and statistically significant difference (at the 1% level). However, when more stringent comparisons are done by comparing the CMM sample with an industry and size match sample and an industry and performance match sample cumulative, the CMM samples cumulative raw returns are lower than both matched samples but were only significantly lower to the industry and size match sample. Therefore, on the basis of the three comparisons, there is weak support for H1B.

Examining the sub-samples, we first observe that the IT sub-sample's cumulative raw returns are significantly better that the S&P 500 index (at the 1% level); but there is no significant difference in cumulative raw returns between the IT sub-sample and both the industry and size match sample and the industry and performance match sample. However, comparing the result of the IT sub-sample with those of the non-IT sub-sample, we see the differences associated with the non-IT sub-sample were more unfavorable. In addition, the non-IT sub-sample's cumulative raw returns are significantly lower than its associated industry and size match sample. Therefore,

Table 3 Raw returns compared with S&P 500 and matched sample 1 year after the announcements

Cumulative raw returns (%)	*All CMM (n = 348)*	*IT (n = 143)*	*Non-IT (n = 205)*	*Smaller (n = 174)*	*Larger (n = 174)*
CMM (1)	−1.181	10.928	−9.083	−4.494	2.815
S&P 500 index (2)	−7.595	−7.030	−8.141	−5.755	−9.612
CAR: (1)–(2)	6.414***	17.958***	−0.942	1.261	12.427***
Industry and size match (3)	5.537	10.896	1.463	4.005	6.692
CAR: (1)–(3)	−6.718***	0.032	−10.546***	−8.499**	−3.878
Industry and performance match (4)	2.284	13.625	−5.497	3.878	0.828
CAR: (1)–(4)	−3.465	−2.697	−3.586	−8.372	1.987
Cumulative raw returns (%)	*Level 2 (n = 66)*	*Level 3 (n = 215)*	*Level 4 and 5 (n = 67)*	*Initial appraisal (n = 98)*	*Multiple appraisals (n = 250)*
CMM (1)	−10.904	1.356	2.252	−3.860	1.368
S&P 500 index (2)	−8.048	−6.843	−9.988	−3.066	−7.519
CAR: (1)–(2)	−2.856	8.199***	12.240**	−0.794	8.886***
Industry and size match (3)	7.293	6.293	0.405	4.845	6.718
CAR: (1)–(3)	−18.198***	−4.937*	1.847	−8.705	−5.351**
Industry and performance match (4)	−0.311	2.751	3.734	4.004	2.564
CAR: (1)–(4)	−10.593	−1.395	−1.482	−7.864	−1.196

*Significant at 10% level, ** significant at 5% level, ***significant at 1% level.

there is support for H2B. A similar pattern emerges between the larger and smaller firm sub-samples. The larger firm sub-sample's cumulative raw returns are significantly better that the S&P 500 index (at the 1% level); but there is no significant difference in cumulative raw returns with respect to its industry and size match sample and industry and performance match sample. However, comparing the larger firm sub-sample result to the results of the smaller firm sub-sample, we see the differences associated with larger firm sub-sample are uniformly more favorable. We also observe that the smaller firm sub-sample's cumulative raw returns are significantly lower than its associated industry and size match sample. Therefore, there is support for H3B.

With respect to the functional scope of the CMM appraisal, both Level 3 and Level 4 and 5 sub-samples were associated with a statistically significant, positive difference in cumulative raw returns when compared with the S&P 500 index. However, the Level 3 sub-sample had significantly lower (at the 10% level) cumulative raw returns when compared with an industry and size match sample; the remaining comparisons for both Level 3 and Levels 4 and 5 were non-significant. In addition, the Level 2 sub-sample shows no significant difference in cumulative raw returns when compared with the S&P 500 index and an industry and performance match sample (though the Level 2 sub-sample cumulative raw returns were lower in both cases). However, when compared with an industry and size match sample, the Level 2 sub-sample cumulative raw returns were substantially and significantly (at the 1% level) lower. What is important here is the pattern that emerges as we look across each of the benchmark portfolios. The results clearly show a favorable improvement in the cumulative raw returns differences as CMM level increases; therefore, there is support for H4B. With respect to the physical scope of the CMM appraisal, the multiple appraisal sub-sample had a statistically significant, positive difference in cumulative raw returns when compared with the S&P 500 index, a statistically significant, negative difference in cumulative raw returns when compared with the industry and size match sample, and a non-significant negative difference in cumulative raw returns when compared with the industry and performance match sample. There were no statistical differences in cumulative raw returns between the initial appraisal sub-sample and any of the benchmark portfolios. However, the multiple appraisal sub-sample's cumulative raw returns are more favorable than the initial appraisal sub-sample. But given the multiple appraisal sub-sample's significant negative difference in cumulative raw returns when compared with the industry and size match sample, it is not possible to confirm or refute H5B. We also run regressions of CARs of different event windows (i.e., (0, 0), (1, 1), (−1, 1), and (−5, 5)) on firm size for different samples. It is only for the multiple announcement sub-sample that our results show a statistically significant positive relationship between firm size and the CARs. For other samples, it is either insignificant or significant for different event windows.

Fama-French (FF) 3-factor and 4-factor Models: We also test the long-run performance of the CMM sample using the FF 3-factor and 4-factor models. In their seminal works, Fama & French (1993) found that by adding the company's firm size and book to market value of equity (BE/ME) variables to the traditional market model, that only includes non-diversifiable risk to measure expected returns, they could greatly increase

Table 4 FF 3-factor or 4-factor model results for CMM sample and sub-samples

		ALL CMM (*n*=348)	*IT* (*n*=143)	*Non-IT* (*n*=205)	*Smaller* (*n*=174)	*Larger* (*n*=174)
FF 3-factor Panel 1: $R_{it}-R_f=a+b(R_{mt}-R_{ft})+s\,SMB_t+hHML_t+e_{it}$;						
Intercept	Coefficient	0.0073	0.0470	−0.0190	0.0000	0.0159
	t-statistics	0.80	4.50***	−1.47	0.06	2.58**
	z-statistics	3.62	4.17	1.27	1.63	3.30
	P-value	0.0003	0.0000	0.2053	0.1027	0.0003
FF 4-factor Panel 2: $R_{it}-R_{ft}=a+b(R_{mt}-R_{ft})+s\,SMB_t+hHML_t+mUMD_t+e_{it}$;						
Intercept	Coefficient	0.0000	0.0447	−0.0308	−0.0118	0.0136
	t-statistics	−0.06	4.70***	−2.10**	−0.68	2.16**
	z-statistics	3.07	4.20	0.52	1.17	3.29
	P-value	0.0021	0.0000	0.5997	0.2434	0.0010

		Level 2 (*n*=66)	*Level 3* (*n*=215)	*Level 4 and 5* (*n*=67)	*Initial appraisal* (*n*=98)	*Multiple appraisals* (*n*=250)
FF 3-factor Panel 1: $R_{it}-R_{ft}=a+b(R_{mt}-R_{ft})+s\,SMB_t+hHML_t+e_{it}$;						
Intercept	Coefficient	−0.0270	0.0154	0.0186	−0.0160	0.0157
	t-statistics	−0.88	1.82*	0.83	−0.92	1.72*
	z-statistics	0.90	3.00	2.24	0.57	4.11
	P-value	0.3657	0.0270	0.0248	0.5710	0.0000
FF 4-factor Panel 2: $R_{it}-R_{ft}=a+b(R_{mt}-R_{ft})+s\,SMB_t+hHML_t+mUMD_t+e_{it}$;						
Intercept	Coefficient	−0.0440	0.0085	0.0165	−0.0225	0.0080
	t-statistics	−1.18	1.04	0.80	−1.24	0.83
	z-statistics	0.50	2.55	2.14	0.51	3.47
	P-value	0.6181	0.0107	0.0319	0.6087	0.0005

*Significant at 10% level, ** significant at 5% level, ***significant at 1% level.

the explanatory power of the model. The 3-factor model is applied by regressing the post-event daily excess returns for stock *i* on a market factor, a size factor, and a book-to-market factor. The 4-factor model is constructed by integrating the Fama & French (1993) 3-factor model with an additional factor capturing the 1-year momentum anomaly documented by Jegadeesh & Titman (1993) and addressed through the creation of a 4-factor model explicitly controlling for momentum by Carhart (1997). Specifically, the 3- and 4-factor models are defined, respectively, as:

$$R_{it}-R_{ft} = a_i + b_i(R_{mt}-R_{ft}) + s_i\,SMB_t + h_i HML_t + e_{it}; \quad (2)$$

$$R_{it}-R_{ft} = a_i + b_i(R_{mt}-R_{ft}) + s_i\,SMB_t + h_i HML_t + m_i\,UMD_t + e_{it}; \quad (3)$$

where: R_{it} = the simple return on the stock *i* of CMM sample; R_{ft} = the return on 1-month Treasury bills; R_{mt} = the return on a value-weighted market index; SMB_t = the return on a value-weighted portfolio of small stocks less the return on a value-weighted portfolio of big stocks; HML_t = the return on a valued-weighted portfolio of high book-to-market stocks less the return on a value-weighted portfolio of low book-to-market stocks; UMD_t = the return on the two high prior return portfolios less the returns on the two prior low return portfolios

A positive intercept for these regressions, a_i, indicates that after controlling for the market, size, and book-to-market ratio (and momentum) factors in returns, the sample firm has performed better than expected. For each stock *i* in the CMM sample, we run a regression using the 3- and 4-factor models. To determine whether the regression intercepts, a_i, are significantly different from zero, we calculate both the *t*-statistics and *z*-statistics with their respective *P*-values. The *t*-statistics are calculated by dividing the mean intercept terms by the cross-sectional sample standard deviations of the intercept terms and multiplying by the square roots of number of firms in the CMM sample. We obtain the *z*-statistics by adding individual regression *t*-statistics across stocks and then dividing the sum by the square roots of the number of regression intercepts.

Table 4 shows the results of the two regressions for our overall sample and each of our sub-samples. We report only the mean regression intercepts and their respective *t*-statistics and *z*-statistics (with *P*-values) for brevity. For the entire CMM sample, the results show positive but non-significant intercepts; thus, H1B is not supported by this method. Examining all the sub-samples, we see positive and significant intercepts in both models for

Table 5 BHAR results for CMM sample and sub-samples

Sample	$\prod$ *(1+R_{it})*	$\prod$ *(1+E(R_{it}))*	*BHAR*	*T-test*
Panel A: BHARs compared with industry and size match				
All CMM ($n=348$)	1.692	1.035	0.656	1.25
IT ($n=143$)	1.079	1.080	−0.001	−0.01
Non-IT ($n=205$)	2.121	1.004	1.117	1.26
Smaller ($n=174$)	2.284	1.016	1.268	1.21
Larger ($n=174$)	1.099	1.054	0.045	0.83
Level 2 ($n=66$)	3.655	1.040	2.615	1.02
Level 3 ($n=215$)	1.266	1.032	0.234	2.21**
Level 4 and 5 ($n=67$)	0.9594	1.048	−0.089	−1.14
Initial appraisals ($n=98$)	2.927	1.045	1.881	1.05
Multiple appraisals ($n=250$)	1.169	1.048	0.121	1.84*
Panel B: BHARs compared with industry and performance match				
All CMM ($n=348$)	0.983	1.031	−0.048	−1.18
IT ($n=143$)	1.049	1.120	−0.071	−1.14
Non-IT ($n=205$)	0.939	0.973	−0.034	−0.62
Smaller ($n=174$)	0.976	1.096	−0.120	−1.53
Larger ($n=174$)	0.989	0.967	0.022	0.92
Level 2 ($n=66$)	0.911	0.969	−0.058	−0.93
Level 3 ($n=215$)	0.988	1.063	−0.076	−1.39
Level 4 and 5 ($n=67$)	1.052	0.9926	0.059	0.59
Initial appraisal ($n=98$)	1.006	1.113	−0.108	−1.15
Multiple appraisals ($n=250$)	0.991	1.012	−0.021	−1.15

*Significant at 10% level, ** significant at 5% level, ***significant at 1% level.

only IT sub-sample and the larger firm sub-sample. In addition, both sub-sample perform better than their respective counterpart sub-samples (non-IT and smaller firms, respectively). Thus, both H2B and 3B are supported. With respect to functional and physical scope, the Level 3 sub-sample and the multiple appraisals sub-sample do show a positive and significant (at the 10% level) intercept for the 3-factor model, but both have a non-significant positive intercept in the 4-factor model. They all show increases in intercept coefficient values as the level increases. The intercept coefficient values are also higher for the multiple appraisals sub-sample than the initial appraisal sub-sample. Thus, the results provide weak support for both H4B and 5B.

BHARs: Long-term performance is also assessed by using *BHAR*s. Building on the work of Ritter (1991), Barber & Lyon (1997) found that *BHAR*s can be used to address different issues regarding portfolio performance. A *BHAR* is the difference between the return on a buy-and-hold investment in a company of interest less the return on a buy-and-hold investment in a similar asset/portfolio. Barber & Lyon (1997) noted that *BHAR*s can overcome several biases such as measurement bias inherent in estimating long-term CARs caused by summing daily or monthly ARs. Specifically, *BHAR* is calculated as:

$$BHAR_{iT} = \prod_{t=1}^{T}[1+R_{it}] - \prod_{t=1}^{T}[1+E(R_{it})], \quad (4)$$

where R_{it}, $E(R_{it})$, and T are defined the same as in Eq. (1). Barber and Lyon (1996) examined both size-matched and performance-matched samples, while Barber & Lyon (1997) argued that by matching sample firms to control firms of similar sizes and same industry will correct for the possible sources of misspecification. Thus, our matched samples (size-matched sample and performance-matched sample) serve as our benchmark portfolios.

We report the results of *BHAR*s for the overall sample and each of sub-samples in Table 5. We test the null hypothesis that the *BHAR*s are equal to 0 with the *t*-test statistic:

$$t_{BHAR} = \overline{BHAR}_{it}/(\sigma(BHAR_{it})/\sqrt{n}) \quad (5)$$

where: $\overline{BHAR}_{it}$ = average *BHAR*; $\sigma(BHAR_{it})$ = cross-sectional standard deviation of the *BHAR*s. n = the number of matched comparisons.

Although the results show a positive return for the entire CMM sample using the buy-and-hold strategy, the *t*-test results are non-significant; thus, H1B is not supported. Of the nine sub-samples, only two (Level 3 and Multiple Appraisals) have positive and significant *BHAR*s, and only with their respective industry and size match sample. All other sub-sample *BHAR*s are non-significant. With the exception of the IT/non-IT sub-sample *BHAR* comparison, there is no consistent pattern of one sub-sample showing superior performance. Even in the case of the IT/non-IT sub-sample *BHAR* comparison, neither *BHAR* is significant. Thus, the tests regarding H2B–5B are inconclusive.

Table 6 Accounting performance (ROA) for CMM sample and sub-samples

Sample	*1 year before (1)*	*1 year after (2)*	*Change (2)–(1)*	*t-test*
All CMM ($n=348$)	10.008	9.410	−0.598	−2.05**
IT ($n=143$)	13.579	14.180	0.601	1.98*
Non-IT ($n=205$)	7.395	6.236	−1.159	−2.76***
Smaller ($n=174$)	6.620	5.803	−0.817	−1.67*
Larger ($n=174$)	13.107	12.709	−0.398	−1.18
Level 2 ($n=66$)	7.350	6.048	−1.303	−2.11**
Level 3 ($n=215$)	10.745	10.180	−0.565	−1.59
Level 4 and 5 ($n=67$)	9.8223	10.2603	0.438	0.61
Initial appraisal ($n=98$)	8.283	6.762	−1.522	−1.96*
Multiple appraisals ($n=250$)	10.133	10.042	−0.091	−0.34
Industry and size match ($n=348$)	10.258	7.354	−2.904	−4.35***
Industry and performance match ($n=348$)	10.014	4.526	−5.487	−7.41***

*Significant at 10% level, ** significant at 5% level, ***significant at 1% level.

Accounting-based Measures (ROA): Our results so far indicate that the CMM sample generally outperforms the market index but not its matched sample 1 year after CMM implementation. Through our use of matched samples we have tried to minimize various long-term market effects associated with industry and firm characteristics. To further test the robustness of our previous results using financial-based measures, we now test our hypotheses using an accounting-based measure of ROA. In this section, we calculate the ROA 1 year before CMM announcements and compare them with ROAs 1 year after the announcements and report our results in Table 6. Before discussing the results associated with the hypothesis, it is important to observe that the majority of ROA differences are negative and significant; this is more a result of the economic conditions at the time of the study. Our conclusion is supported by the fact that both the industry and size-matched sample and the industry and performance-matched sample show a significant and negative change in ROA over the exact same time periods.

Examining the ROAs of the CMM sample, we observed a decrease of 0.60% in the post-CMM period compared with the pre-CMM periods. However, the change in the ROAs of the CMM sample was superior to that of the matched samples as the size-matched sample experienced a decrease of 2.90%, while the performance-matched sample experienced a decrease of 4.57% over the same test period. Thus, H1B is supported by this method.

Comparing the various sub-sample pairing, we first see a significant (at 1% level) decrease in the ROA of non-IT sub-samples while the IT sub-samples showed a significant (at 10% level) increase in ROA, supporting H2B. Contrasting the results of the two firm-size sub-samples, the smaller firm sub-samples shows a significant (at 10% level) decrease in ROA while the larger firm decrease is smaller and non-significant; therefore, H3B is supported. Examining the results associated with functional scope of the CMM, we see that the Level 2 sub-sample shows a significant decrease in ROA, the Level 3 sub-sample shows a non-significant decrease in ROA, and the Level 4 and 5 sub-sample shows a non-significant increase in ROA. Thus, these results support H4B. Finally, with respect to physical scope of the CMM, the Initial Appraisal sub-samples results reveal a significant (at the 10% level) negative ROA compared with non-significant and smaller decrease in ROA for the Multiple Appraisals sub-sample. Therefore, H5B is also supported.

Although results in Table 6 supported our hypotheses, we need to interpret the results with caution. There are obviously many factors that might also influence the ROA changes during the 2-year period. We need to be careful in attributing the ROA changes to the single factor of CMM. In order to test whether the change of ROAs can be partially explained by the implementation of CMM, we use regression analysis. We retrieve all the firms that have available data for ROAs (around 4700 stocks for each year) during our sample periods, and calculate the changes of ROAs of each stock. Then, we define CMM as dummy variable that equals 1 if the stock belongs to CMM sample for that year, and equals 0 otherwise. We run a regression on the changes of ROAs on CMM and find that CMM dummy variable is positive and statistically significant (at the 10% level), meaning that the CMM sample has higher ROAs compared with the firms that do not adopt CMM. The regression results are omitted for brevity but are available upon request from the authors.

Sensitivity of Trading Costs on Trading Profitability: Our IT sample has demonstrated superior returns in every measures of short-run and long-run stock performance. However, these results have yet to consider the impact of trading cost. Consistent with Tetlock *et al* (2008), we estimate the impact of reasonable transaction costs on the trading strategy's profitability for the IT sample. To judge the sensitivity of profits to trading costs, we recalculate the trading strategy returns under the assumption that a trader must incur a round-trip transaction cost of between 0 and 10 bps. Table 7 displays the raw and risk-adjusted abnormal annualized returns under different cost assumptions. Raw ARs are the cumulative annualized raw returns relative to S&P 500 index, while

Table 7 Sensitivity of trading profits to assumptions of trading costs for IT sample

Trading cost (bps)	*Raw abnormal annualized raw returns (%)*	*Risk-adjusted annualized abnormal returns (%)*
0	17.958	11.891
1	15.428	9.361
2	12.898	6.831
3	10.368	4.301
4	7.838	1.771
5	5.308	−0.759
6	2.778	−3.289
7	0.248	−5.819
8	−2.282	−8.349
9	−4.812	−10.879
10	−7.342	−13.409

the risk-adjusted ARs are the annualized FF 3-factor loadings of the IT sample shown in Table 4.

From the evidence in Table 7, we see that the raw abnormal return is no longer positive after 8 bps transaction costs per round trip, and the risk-adjusted abnormal return is no longer positive after 5 bps of transaction costs. We cannot rule out the possibility that more sophisticated trading rules that exploit the time-series and cross-sectional properties of the IT stocks could economize trading costs resulting in profitable conditions.

Discussion

The premise of our research is that a firm's CMM investments will yield both a positive short-term and long-term return. A summary of the individual hypotheses tested is provided in Table 8. Like the results of Morris & Strickland (2008), which were based on 98 CMM announcements taken from Lexis/Nexis, our results, based on 348 observations taken direct from the SEI CMM Class A appraisals web site (http://sas.sei.cmu.edu/pars/pars.aspx), show the market reacts favorably on the days surrounding the company's official appraisal date. We also extend the work of Morris & Strickland (2008) and Gao *et al* (2010) by considering contextual factors such as industry classification, firm size, and maturity of implementation.

Analysis of the IT sub-sample reveals that IT firms benefit more by adopting the CMM relative to non-IT industry firms. This difference may be attributed to investors associating benefits of CMM practices with firms in the IT industry rather than firms outside the IT industry. Contradictory to the notion that investors place more value on the discloser of information by small firms, our results show, at least with respect to the CMM, that larger firms benefit more in the short-term from the CMM than smaller firms. It maybe, in the case of the CMM, that investors are cognizant of the criticisms associated with its use by small firms (Ngwenyama & Nielsen, 2003) and believe smaller firm may find it more difficult to achieve the benefits espoused by the CMM. Compared with Levels 2 and 4, Level 3 and 5 appraisals represent a significant step forward in the CMM (Gopal & Gao, 2009). As anticipated, firms achieving a Level 3 did show statistically significant, short-term CARs within a 3-day range around the event date. However, our results indicate non-significant short-term CAR values with respect to the Level 4 and 5 sub-sample. Taking a closer look at the AR values associated with Level 4 and 5 sub-samples, we see significant variability around the event date, resulting in non-significant CAR values. The primary driver for these results could be related to small sample size. In addition, while Level 5 appraisals are more common in India, where 25 of the 42 Level 5 are based (Ethiraj *et al*, 2005), Level 5 appraisals in the U.S. are more rare. In part, because of rarity, our data had sample size limitations requiring us to combine Level 4 and Level 5 firms into a single sub-sample, which may be damping the true impact of Level 5 firms. It should be noted that there are only five companies that have available data from CRSP in our Level 4 and 5 sample. The event study result for only the Level 5 appraisals are statistically significant (at the 10% level) positive CARs of 0.63% over the event window of (−1, +1). We also find that firms appraised at the CMM Level 2 showed a statistically significant, short-term CAR over multiple time segments around the event date. Since Level 2 is the first appraisal firms must successfully complete, investors may not be fully aware of these firms' CMM activities. Thus, the market maybe adjusting the firm's stock price, perceiving that such adoption is a signal of the firm's commitment for future improvements, to incorporate this new publicly available information. Finally, we could not confirm or refute H5A regarding the short-term impact of the physical scope of CMM implementations. However, our results do indicate that CMM appraisal, be it the initial or through subsequent appraisals, do add value in the short term.

Event study research, especially in the IT literature, has predominately looked at the short-term impact. However, short-term results should be viewed with some caution since dissemination of the news surrounding an event can be confounded by the different channels where investors obtain the information (Goh & Ederington, 1993; Huberman & Regev, 2001). Using a longer short-term timeframe and taking great care to better match sample characteristics, some of our results show variability around the event though there is no evidence of a systemic issue and most of the significant values are in the 0 to +1 day timeframe. However, given the potential variability associated with short-run analyses, we have also conducted several different analyses involving longer-holding periods.

Because of the added complexity, we conducted several different long-run analyses using various methods and controlling for various known factors identified in our literature review.

Table 8 Summary of research hypotheses

No	*Hypothesis*	*AR*	*CAR*	*Long-term CARs*	*FF*	*BHAR*	*ROA*
1A	Successful CMM implementations will have a short-term positive impact on a firm's financial performance	Supported	Supported				
1B	Successful CMM implementations will have a long-term positive impact on a firm's financial performance			Weakly supported	Not supported	Not supported	Supported
2A.	The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for IT firms than for non-IT firms	Supported	Supported				
2B.	The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for IT firms than for non-IT firms			Supported	Supported	Inconclusive	Supported
3A.	The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for smaller firms than for larger firms	Inconclusive	Contradictory				
3B.	The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for larger firms than for smaller firms			Supported	Supported	Inconclusive	Supported
4A.	The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of greater functional scope than for implementations of lesser functional scope	Inconclusive	Contradictory				
4B.	The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of greater functional scope than for implementations of lesser functional scope			Supported	Weakly supported	Inconclusive	Supported
5A.	The short-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of lesser physical scope than for implementations of greater physical scope	Inconclusive	Contradictory				
5B.	The long-term impact of successful CMM implementations on a firm's financial performance will be more favorable for implementations of greater physical scope than for implementations of lesser physical scope			Inconclusive	Weakly supported	Inconclusive	Supported

Overall, our tests on the long-term stock return performance indicate that the raw returns of the CMM sample outperform those of the S&P 500, but they are not significantly different from the returns on the matched sample in most sub-samples. Thus, we find marginal support for long-term impact of the CMM but only to the extent that comparisons are made against a broad market index. Across different sub-samples, we find in three of four analyses support H2B and 3B as the IT sample, and the larger firm sub-sample show positive ARs compared with non-IT sample and the smaller firm sample. We also find marginal support for H4B and 5B. Overall, these results speak to the notion of economies of scale and scope. The CMM allows IT, larger, higher capability, and more diverse firms to better leverage their knowledge and resources through necessary controls and coordination mechanisms. Thus, allowing these firms to produce better quality products, while meeting budgeted cost and schedules.

In addition, over longer-time periods, overall, the raw returns results indicate that although stocks completing CMM appraisals generally outperform the S&P 500 index over longer-holding periods, they do not outperform a matched sample. We do find support that firms from the IT industry, of larger size, achieving higher levels of maturity and having multiple successful appraisals, are rewarded with longer-term excess returns relative to counterparts in the broad market. Both IT and the larger firms sub-samples have significant ARs 1 year after the appraisal date using FF factor models. However, the entire CMM sample and several sub-samples generated marginally positive or negative non-significant results, when paired with matched sample. Business executives must take caution interpreting the results associated with CMM level. Our results do not imply that CMM 'does not matter', it may mean that market views the costs associated with the CMM equivalent to the benefits generated. Thus, when compared with like firms, the CMM helps firms to achieve competitive parity. This finding is an important result since most firms begin to engage in CMM practices because they are falling behind in delivering quality software and systems on-time and on-budget. The fact that the market perceives that the benefits of CMM compensate for the costs within a 1-year period is impressive given the substantial investments typically associated with CMM appraisals. This supports the 'quality is free' principles (Deming, 1986; Juran, 1988) that the CMM is based on (Humphrey, 1989). Past research found process improvement effects take longer to materialize (Hendricks & Singhal, 2001b; Corbett *et al*, 2005); thus, the CMM may provide a basis for significant increases in future returns. In addition, we find that the entire CMM sample and every sub-sample were more resilient to the worldwide economic crisis that is associated with the post-CMM period as all accounting-based ROA measures were superior compared with both the industry and size matched samples and the industry and performance matched samples.

Limitations and directions for future research

There are some key limitations associated with this study that may provide future research opportunities. A limitation of most research using the event study methodology is that it only provides a very high-level view of firm performance; our research suffers this same limitation. While it is true that the impact of the CMM would be more directly observable at the project/process level (i.e., the product quality, productivity, project costs, project timeframe, etc.), such process level data from publicly available sources are not readily available (Corbett *et al*, 2005). However, given that the majority of CMM research has been conducted at the project or process level of a single or small group of firms, this research represents a nice contrast and complement by examining the aggregated CMM effect at firm level.

The event study methodology focuses on the short-term market impact of the event under study may be viewed as another limitation. However, by coupling these results with longer-term holding period analysis our research provides both a shorter-term and longer-term market assessment of the value of the CMM. In addition, the analysis of the impact on accounting-based measures, relative to benchmarks, allows us to gain some insight to the firm-level effects of CMM. The use of accounting-based measures helps to mitigate concerns that factors other than CMM adoption may explain the longer-term holding period results for firms within the sample. By using accounting-based measures, we are better able to understand the impact on operational efficiency that corresponds to the CMM adoption. Thus, our research has conducted both shorter- and longer-term analyses using various models as a way of providing a more holistic view of the CMM's impact.

While we identify the appraisal date for each individual firm as $t=0$ for our study, the appraisal process takes from 6 months to 18 months to complete. Therefore, there is some likelihood that firms have already leaked their progress to the press or their shareholders concerning their appending appraisal results before the actual event date. Such an occurrence would result in price run-up leading up to the event dates, degrading the short-term impact of the CMM announcements. It is also possible that word could spread further after the appraisal end date as companies issue press releases touting their CMM appraisal. Therefore, identifying a specific date for a market reaction is somewhat problematic. Our study is not unique in this regard. Huberman & Regev (2001) tracked the stock market reaction over a 15-month 'event window' while studying the response to EntreMed's potential development of cancer-curing drugs. Similarly, events such as changes in bond rating are typically studied over several announcement windows leading up to the actual event (e.g., Goh & Ederington, 1993). Given that our short-term results are similar to finding of

Morris & Strickland (2008), who used a different CMM event data source with ARs concentrated around the event day, it is reasonable to assume that we have accurately captured the event.

Since process improvement effects may take longer to materialize (Hendricks & Singhal, 2001b; Corbett *et al*, 2005), future research may also seek to replicate this study using a longer-time frame than the 1-year time horizon used in this study. Examining what impact CMM failures have on firm's market value may be interesting. Results of a recent study by Bharadwaj *et al* (2009) indicate that IT failures may negatively impact a firm's market value. Our study only considers firms that have achieved a successful level appraisal; however, many firms fail in their CMM implementations (Gefen & Zviran, 2006). Finally, our data set only included U.S. firms from SEI's global appraisal database. Therefore, there is potential for future research to be done on cross-country comparisons.

Conclusion

This research extends the current CMM literature by investigating both the short-term and long-term differential impact of successfully completed CMM investments based on firm size, industry, and maturity of CMM implementation. Using a separate data source, our results support the finding of Morris & Strickland (2008) that the CMM has a positive, significant, short-term impact on firm performance. Expanding on the work of Gao *et al* (2010), our research found contextual factors regarding the industry setting, firm size, and type of implementation may all play a role in determining the impact of the CMM on firm performance. There were also differences associated with the short-term and long-term impacts and the various performance methods used. Overall, our results show that at best the CMM generated significant abnormal positive, and at worst firms adopting the CMM generate benefits that cover the costs associated with the CMM appraisal.

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